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REDUCING LONG TERM METHANE EMISSIONS RESULTING FROM COAL MINING

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1. INTRODUCTION

Methane has been a problem for almost as long as coal has been dug from the ground. The disasters caused by firedamp explosions underground have led to laws being imposed upon the permissible levels of firedamp in mine ventilation. These constraints on the concentrations of methane define ventilation requirements and limit the production rates possible from mining units. The need to provide methane control has led to the use of drainage techniques to extract methane at high concentrations from the strata and vent it safely. Methane drained from mines has been used as a fuel source and in recent years there has been increased pressure to use the resource to its full advantage. Methane emitted into the main ventilation has now begun to be seen as a potential fuel source, inspired by a desire to reduce the pollution released to atmosphere, as methane is a greenhouse gas with a forcing potential many times higher than that of carbon dioxide.

2. METHANE CONTENT, PRESSURE AND PERMEABILITY

Methane contents of British Coal seams vary from trace to 20 m^3/t[1]. A survey of British Coal mines in operation in 1993 [2] provided information on the gas contents of the coal seams being mined. These were in the range of less than 1 m^3/t to almost 15 m^3/t. The average gas content, weighted by production from the individual collieries, was 4.7 m^3/t, with over 60% of collieries mining seams within the range of gas contents of 3 m^3/t and 6 m^3/t.

It has been found that gas pressures of coal seams in the UK are generally less than one fifth of hydrostatic pressure [3], although examples of gas pressures approaching hydrostatic are known. Hydrostatic pressures usually obtain where coal seams and the intervening strata are permeable to the surface. Under these conditions groundwater permeates the ground, pressurising the coal seams to hydrostatic pressures. This condition is not one that generally obtains within the UK nor, from results in the literature, in other countries. The under-pressure of UK coal seams is due to the low permeability of the coal seams and the intervening strata, which isolates them from the flows of groundwater. The lack of recharge from new water flow from the surface is attested to by the high salinities of water which exist in Coal Measures strata.

The permeabilities of coals in Britain are generally low, compared with some types of coals encountered in parts of the USA and Australia, for example. The fact is clearly demonstrated by flows of gas, much higher than are found in the UK, entering headings in some mines in those countries. Flows from in seam boreholes have also shown large differences in flow between some overseas locations and within the UK where pressures are similar, although at much deeper levels in the UK. An exception to this is found at a colliery in North Wales, where headings were frequently gassed off and required in-seam drainage to reduce the methane flow. The difference

in permeability is likely to be due to a combination of the nature of the coal and the confining pressure which decreases the permeability.

The major sources of gas within the strata are the coal seams. However, reservoir rocks have been encountered during mining operations which have released quantities of methane equal to or in excess of those released from the coal seams. These sources are usually sandstone beds with high porosity which are located in natural gas traps such as anticlines and fault bounded blocks.

Essentially the flow from solid coal in British mines is very slow. To produce significant flow the permeability of the coal needs to be increased, and this result is obtained by the process of mining disturbance.

3. MINING INDUCED GAS EMISSION

The process of mining has two main effects which produce flows of methane. The first is the internal disruption of the coal within the coal seam through extensive fracture. The second is the opening of pathways through the strata to enable the gas to leave the confines of the seam.

The rate of release of gas from competent UK coals is low, due to the low permeability and gas pressure. Large widely spaced fractures through the coal seams would not be sufficient to increase the rate of desorption significantly. The seam needs to be fractured at the small to microscopic scale, the fractures not necessarily obvious in a large specimen. Such fracturing separates the solid coal into an assemblage of fragments, which, due to their size, allow their gas to be released over much shorter time periods than normal. However, to release the gas requires some dilation of the strata; to produce a lower pressure reservoir for the gas to flow into and to produce widening of the fractures to encourage the flow of gas from the coal.

A longwall face produces a void behind it as it advances. The creation of the void means that the weight of rock above can no longer be supported and thus the stresses in the surrounding rocks are thrown outwards into the strata at the edges of the excavation. The concentration of very large stresses at the edges produces failure, throwing the peak stress some metres forward of the face line and gate sides. This peak stress region is referred to as the front abutment and extends up and over the waste in an arch, throwing its weight away to the sides. A similar condition exists in the floor of a district, due to the release of vertical confining pressure on the underlying rocks. The level of peak stress reduces with distance from the working as the "arch" closes and the concentration of the stresses decreases. The ground behind the face sinks into the void, through fracture, creating dilation in the strata around the working.

The stresses due to the front abutment affect the coal seams greatly, as they are amongst the weakest materials in Coal Measures strata, mudstones only being comparable in strength. The high confining pressure and the anisotropic stress field of the front abutment zone disturb the internal structure of the coal seam, as required to produce degassing, while the movement of the strata produces the dilation required for gas to flow from the coal. Reservoir rocks have been found to behave similarly to coal seams in that they appear to release their gas only under the impact of mining disturbance. Evidence for this comes from the observation that the emissions of methane from sites with emissions from reservoirs follow closely those expected from coal seams alone, albeit increased by a large factor [4].

The zone around the coal working which releases methane into the working is a function of the size of the excavation and the depth of extraction [5]. Both factors serve to increase the stresses obtaining around the working, which both increases the degree of fracture and the size of the fracture zone. By virtue of this, drivages tend to release gas from the mined seam alone, while longwall districts release gas from regions up to about 200 m distant. The limit in the range of gas emission, especially for large extractions is most likely caused by a reduction in inter-seam permeability due to regions of compression. Within this compression envelope methane may still be released for some time after mining has occurred, although at lower flows due to the recompaction of the strata and the reduced gas pressure due to degassing.

4. RADICAL DRILLING OPTIONS FOR IMPROVED METHANE CAPTURE

4.1 Scope for Improvements

Current methane drainage practice in the UK and elsewhere is to drill a number of cross measure holes from workings around an active longwall which are designed to intersect fractures created during the mining operation. Gas liberated during mining will make its way down the pressure gradient to these fractures and hence to the drainage boreholes, which are maintained under suction to deliver gas to the surface.

Additional methane drainage options have been under consideration in the UK for some time in order to improve the percentage of methane captured. The goal of this work is to reduce the volume of methane yielded to the mine atmosphere, and to increase the volume of methane delivered to the surface for subsequent commercial benefit. The available options fall into three categories, namely:-

- Attempting to drain methane from coal measures before mining, using multiple boreholes drilled into the coal targeted for extraction.
- Attempting to drill long boreholes into strata above or below planned longwalls which will contribute to drainage efficiency throughout the life of the longwall.
- Attempting to drain gas after longwalling is completed, by drilling boreholes into the volume of enhanced porosity and permeability created by the extraction of the coal.

Each of these options offers a technical challenge connected with the drilling operation itself, quite apart from its likelihood of commercial success in terms of the additional volume of gas collected. The UK experience is outlined below.

4.2 Pre-drainage of methane from coal measures

Pre-drainage of methane has been successfully pursued outside the UK[6], and work of this kind is the basis of Coal Bed Methane (CBM) projects around the world. Boreholes are drilled along the coal seam, either horizontally from within the mine or initially vertically from the surface, and gas drained either through the natural permeability of the coal itself or through enhanced permeability induced by hydrofracture.

At face value, by far the more attractive option should be to drill in-seam holes from within the mine itself, since in this case every metre drilled provides surface area for drainage of the target strata. However, there is much experience of horizontal in-seam drilling within the UK coalfields, generally for exploration purposes, and this experience has frequently proven expensive. A number of factors have contributed to the difficulties encountered, namely:-

- When drilling from the surface down, control of hydrostatic pressure within the mud column is vital in order to maintain stability of the borehole. When drilling horizontally from within a mine roadway at typical UK depths of 500 m - 1000 m, out into strata of in-situ stress resulting from this depth of burial, stability of the borehole wall depends solely on the mechanical strength of the relevant strata. In all but a few coal seams, the inherent coal strength has proven insufficient to provide routinely favourable drilling conditions.
- In-situ stress in the vicinity of an extracted longwall differs quite strongly from the stress-field prior to extraction, with a marked increase in vertical stress 20 or so metres from the extraction. Thus, particular difficulty has been found in drilling into virgin areas alongside extracted longwalls.

- When drilling closely parallel to the bedding plane of highly laminated coals, boreholes will intersect strata at very low angles. Where a hole intersects an argillaceous band at such low angles, hydration of the clays by drilling fluid can cause swelling which traps a considerable length of drill stem, causing failure of the borehole.

- Typical surface drilling rigs for exploration in the UK coalfields provide around 200 hp to the winch and rotary table. Rigs able to work in the restricted dimensions of a mine roadway generally provide less than 50 hp. Thus, any problems resulting in trapping of drill stem are less likely to be overcome when drilling from underground.

While technical "fixes" may be considered to most of these problem factors, together they conspire to make the cost per metre of long in-seam boreholes relatively high and very unpredictable. While there are exceptions the general situation is that multiple in-seam degassing holes have proved a very uncertain commercial proposition, even without the concerns (expressed in section 2 of this paper) about the potential make of gas from such holes once they are in place.

Hence, it has been necessary to consider the option of drilling from surface, with the possibility of deviating a hole to run sub-parallel to the coal to be degassed. This, of course, is the basis of the CBM industry, which has not as yet proven itself commercially in UK conditions. It may therefore be prudent for coal mine operators to await information on the technical and commercial success of such enterprises before investing heavily in this direction.

4.3 Pre-drilling drainage holes above or below a longwall prior to extraction

Three recent attempts have been made to drill long boreholes above or below a target seam to locations which are expected to collect gas during the mining operation. This kind of work may best be likened to a CBM project in which the permeability enhancement is achieved not by a conventional hydrofracture operation, but by the massive fracturing resulting from longwalling.

In two of these attempts, each drilled above the planned longwall, all the drilling limitations listed under section 4.2 of this paper were encountered, and neither project yielded commercially sensible quantities of gas or contributed materially to methane clearance from the mine atmosphere.

In the third trial, currently in progress, holes are being drilled along a seam about 3 metres below the coal to be longwalled. The seam being drilled and a gas sand associated with it are known to contribute strongly to the make of gas during mining. It is hoped that a significant proportion of this gas will be captured by the additional drainage holes.

So far this operation has progressed well, due largely to the strength of the coal concerned, and the relatively short (around 100 m) nature of the holes being attempted. However, it is too early to provide a full environmental and commercial assessment of the project.

4.4 Post-drainage of methane from longwall goafs

The possibility of drilling, either from surface or underground, into an area above a longwall which has already been extracted may offer the best chance of commercial returns in terms of gas made available for subsequent use. It may also provide some reduction in gas reaching the mine atmosphere by virtue of a decrease in migration of gas from previously extracted areas into current workings. The concept is similar to previous abandoned mine drainage schemes[7,8], in which access to collieries has been maintained via shafts or boreholes after closure.

Projects of this kind are apparently being developed in the US and Poland and have been under consideration in the UK for several years[9]. One major exercise has been worked up over the past two years as a collaboration between IMCL and a US gas company. The issues concerned are complex, involving a range of hurdles to cross relating to liabilities, health and safety,

planning and production permits and ownership. In addition, work of this kind has to be carried out against the background of one vital unknown quantity, namely the rate at which gas is being lost from the man-made reservoir by diffusion and displacement by rising mine waters.

However, the commercial potential involved in the many hundreds of closed collieries around the UK must justify investment. Ideally, such projects should target areas where a large number of longwalls have been extracted beneath a suitably impermeable cap rock, preferably within an anticline or fault trap structure. For the reasons listed in section 4.2, surface drilling would be favoured, and while there are technical challenges involved in drilling into destressed ground, there are no problems which have not previously been encountered and overcome during exploration of the UK coalfields.

The pressures, purities and in-place volumes of gas anticipated in such projects are probably not sufficient to generate sufficient income for long pipelines to be constructed. Hence, gas use would need to be centred close to the extraction borehole. However, given the fact that redevelopment of closed colliery sites will frequently involve the creation of light industrial and retail units with considerable heat and power requirements, this restriction may not prove too onerous.

Given, also, that in many instances gas trapped within old mines may eventually migrate to the surface, leading to a risk of dangerous accumulation, active draining of this kind will have positive environmental benefits.

CONCLUSIONS

Experience in the UK has shown that ambitious methane drainage projects involving pre-drilling of long horizontal boreholes within or close to coals prior to mining have generally proven to be technically demanding and expensive. This does not mean that they should no longer be considered, and in particular cases where the geology is expected to be favourable, further work will be pursued. This may be especially justified where the borehole to be drilled will have exploration value to the mine.

The option of degasssing abandoned mine workings offers fewer technical demands and may have been insufficiently pursued in the UK. While the legal, regulatory and commercial frameworks against which this work must proceed are complex, the potential resource value involved justifies the pursuit of pilot projects.

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